Hoang Tu Huynh
Evelyn Vu
Project 3: Game
Professor Daisy Tang

# Enhancing AI Performance in 4-in-a-Line Game Through Advanced Evaluation Function and Alpha-Beta Pruning Algorithm

## Introduction

The goal was to develop a highly efficient and intelligent AI for the 4-in-a-line game, a variant of the classic connect-four game. This endeavor involved creating an evaluation function that accurately assesses the game board and implementing an alpha-beta pruning algorithm to optimize the decision-making process. The game's complexity lies in its requirement for strategic depth and foresight, making it an ideal candidate for advanced AI techniques.

## Evaluation Function Development

- Simplicity and Depth Trade-off: The evaluation function was crafted to balance simplicity with strategic depth. A simple evaluation function allows for a deeper search within the same computational constraints, which is essential for foreseeing future game states.
- Scoring Mechanism: The function scores the game board based on the immediate threats and opportunities. It prioritizes moves that lead to an immediate win (+10) and moves that block the opponent's immediate win (-10), thereby focusing on the most crucial aspects of the game.
- Future Game States: The function was designed to not only assess the current board state but also to anticipate potential developments, ensuring that the AI makes strategically sound decisions.

## Alpha-Beta Pruning Algorithm Implementation

- Pruning Technique: The alpha-beta pruning algorithm was implemented to optimize the game tree search. This technique efficiently prunes branches of the game tree that do not require evaluation, significantly speeding up the decision-making process.
- Iterative Deepening Framework (IDF): To maximize the algorithm's efficiency, IDF was integrated. This approach allowed the AI to search as deep as possible within a given time frame, adjusting the depth of search dynamically based on the time constraint.

- Move Ordering: We introduced move order to enhance the algorithm’s performance further. The AI prioritizes moves based on their potential impact, examining the most promising moves first. This results in early pruning and faster searches.
- Time Management: The algorithm was designed to manage time effectively, ensuring that the AI remains responsive without compromising the depth and quality of its decision-making.

## Conclusion

The implementation of a well-balanced evaluation function combined with an optimized alpha-beta pruning algorithm has significantly enhanced the AI's performance in the 4-in-a-line game. The AI is now capable of making strategic decisions rapidly, foreseeing future developments, and responding effectively to the player's moves. The integration of move ordering and iterative deepening has further bolstered the AI's efficiency, making it a challenging opponent in the game. This project not only demonstrates the effectiveness of these techniques in game AI development but also serves as a model for similar strategic board games.